Instrumental Measurements of color Changes in Sausage

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INTRODUCTION

Meat industries have vast experience in importance of proper color of sausage and other meat products for the willingness of a consumer to accept a food. The extend to which a consumer will allow variation in the color of a food is determined by subjective preconceptions which are a result of custom and usage. The preconceptions applied by a consumer serve as her color preferences and criteria of food quality. Because the color preferences of the consumers are not uniform the food industry may accept as normal some variability in the colors of foods. The tolerance limits of color variation of a food applied by food industry and followed in the production have to correspond with the acceptability among the consumers and the quality criteria of food.

Although the final judgments of the colors of the foods are visually made by the consumers there is a need in the food industry to use simple physical instruments for color evaluations both for the quality control of production and for the product development. There are several types of instruments available which fit routine use. In our study Hunterlab D 25 Color and Color-Difference Meter was used. This instrument is applicable to measure the color of solid specimen, like sausage, and allows to describe the color dimensions which correspond to the impressions of colors on the human eye.

SPECIFICATION OF COLORS

An international concept for specifying colors was developed by C.I.E. (Comission Internationale de l'Eclairage) which defined three unreal primaries $\underline{X}$, $\underline{Y}$ and $\underline{Z}$ essential for human eye to match colors when illuminated by a standard light source and viewed by a standard observer. The tristimulus values, $\underline{X}$, $\underline{Y}$ and $\underline{Z}$, can be determined by measuring the spectral transmittance or reflectance curve of a color and applying the distribution coefficients

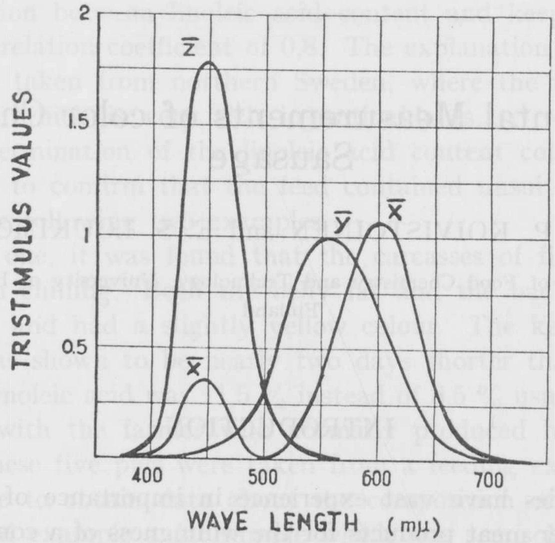

Figure 1. *Equal Energy Distribution Curves of the C.I.E. Standard Observer.* (1).

of energy, $\bar{x}$, $\bar{y}$ and $\bar{z}$, of the primary values at any wavelength when the total spectral energies of the primaries are equal (Figure 1).

The tri-stimulus values can be expressed more simply. The lightness or luminosity of a color is ascribed to Y and the chromaticity (dominant wavelength + purity) of the color is determined by the trichromatic coefficients, x, y, and z.

$$x + y + z = 1$$

$$x = \frac{X}{X + Y + Z}, \quad y = \frac{Y}{X + Y + Z}$$

The trichromatic coefficients, x and y, can be plotted in a C.I.E. chromaticity diagram (Figure 2) for determining the dominant wavelength and the excitation purity of the color. The specification of any color in terms of lightness, dominant wavelength, and excitation purity is considered to correspond fairly well to the subjective responces of the eye to any color.

The Hunterlab D25 Color and Color Difference Meter measures color dimensions L, a, and b:

L measures lightness and varies from 100 for perfect white to zero for black; corresponds to the C.I.E. Y

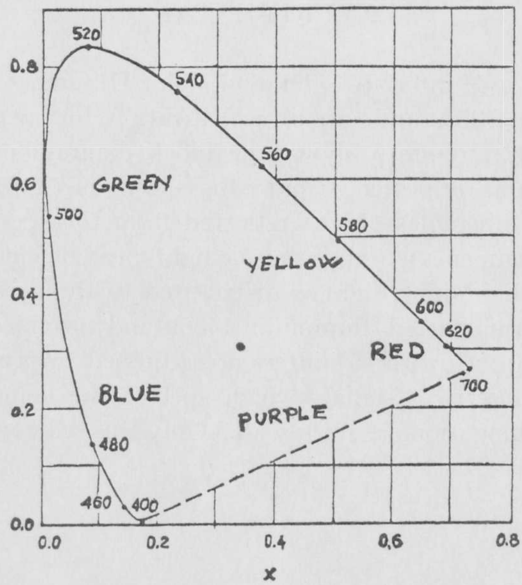

Figure 2. *C.I.E. Chromaticity Diagram (1).*

a measures redness when plus, gray when zero and greeness when minus; corresponds to the C.I.E. Y and X

b measures yellowness when plus, gray when zero, and blueness when minus; corresponds to the C.I.E. Z and Y

Figure 3 illustrates the rectangular surface-color solid of three dimensional graph of colors with the L. a and b dimensions. The L, a and b values can be converted into the C.I.E. values if this kind of specification of a color is wanted.

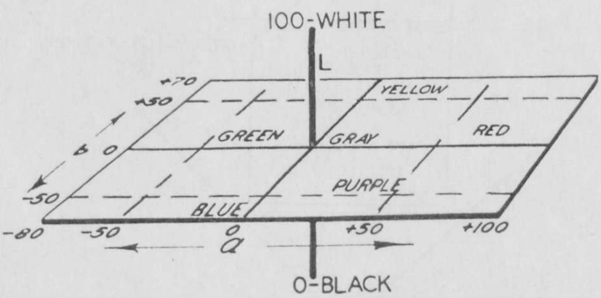

Figure 3. *The Rectangular Surface-color Solid with Dimensions L, a and b (2).*

EXPERIMENTAL

In this study, a Hunterlab Color and Color-Difference Meter with basic instrument Model D25A and circuit modification for measuring L, a, and b values was used. Figure 4 shows the block diagram of this instrument. Light from one lamp is projected onto the specimen (2-inch diameter) from opposite sides at 45° angles. Light reflected from the specimen and perpendicular to the specimen viewed, enters a light pipe of clear plastic. At the upper end of the light pipe, light is distributed to three vacuum phototubes mounted in a thermostatted aluminium block and provided with tristimulus filters. The phototubes with the filters are adjusted to produce via the measurement circuit electrical signals which specify the color of the specimen e.g. on the three dimensional L, a, b scale. Only this scale was used in the present study.

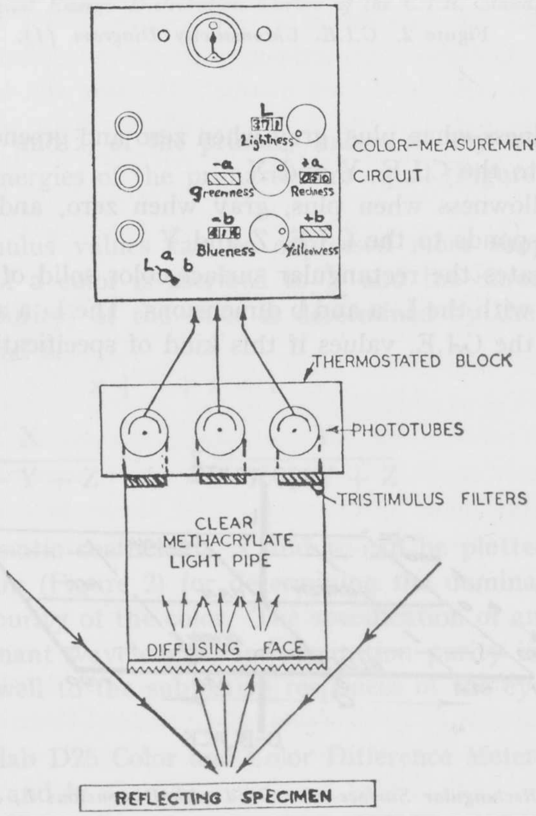

Figure 4. *Block Diagram of Hunterlab Color and Color Difference Meter (2).*

For standardizing the instrument following color standards supplied with the instrument were used:

— White standard No. D25 3143; L = 92,5, a = 1,0, b = 0,6

— Pink standard No. D25 3145; L = 75,1, a = 12,5, b = 9,9

Standardization was made according to the operation manual of the instrument.

In the study, a series of experiments was made for improving color properties of cooked and smoked sausages, especially the stability of color of cut surfaces when exposed to air. The food additive composition of sausages was varied; the rest of the recipe of each type of sausage used in a factory (Karjakunta, Helsinki) was retained unchanged.

As far as the applicability of the Hunterlab Meter to measuring the color or color changes of sausage is concerned, the results from different experiments were basicly very similar. For this reason only one experiment is demonstrated in this connection.

From one Finnish type of cooked and smoked sausage (»lauantai»-sausage, it is like bologna) three equal batches, I, II and III, except food additive composition, were made by a regular process within a day. Sausages were stored overnight at 5° C. Next morning, 5 slices, 8 mm of thickness, were cut to represent each one of the sausage batches. Immediately after cutting, the slices were measured for the color and then stored for 4 hours in a regular refrigerated retail store counter (UPO Osakeyhtiö, Nastola, Finland) at 5° C and about 50 % relative humidity; one side of each slice to be measured for the color at one-hour intervals was exposed to air and light of the counter.

RESULTS

Technical. The material homogenity of »lauantai»-sausage made it very fit for color measurements. The deviations of single measurements of one material from each other were very small. An experienced person could make 20 to 30 measurements in ten minutes. Other types of sausages which contain irregularities, like fat and meat cubes, in the cut surfaces are more difficult to measure accurately.

The instrumental dimensions of the colors and color changes were found to well correspond with visual evaluations of the sausages.

L, a, and b Dimensions. In Table 1 the L, a and b values of the colors of three »lauantai»-sausage batches with different food additive compositions are given with standard errors (s).

Table 1. *Color Dimension of Sausage Cut Surfaces Exposed to Air and Light as Modified with Exposure Time*

Time	*L*	$s\bar{L}$	*a*	$s\bar{a}$	*b*	$s\bar{b}$
Batch I:						
0 h	63,4	0,011	11,9	0,001	9,8	0,000
1 h	62,9	0,011	11,1	0,006	11,0	0,007
2 h	62,2	0,001	11,0	0,008	11,3	0,010
3 h	61,3	0,006	10,9	0,018	11,5	0,012
4 h	61,1	0,013	11,1	0,017	11,7	0,007
Batch II:						
0 h	63,0	0,007	12,1	0,007	9,9	0,005
1 h	62,8	0,006	11,0	0,000	11,4	0,001
2 h	62,0	0,008	10,8	0,006	11,6	0,006
3 h	61,4	0,024	10,1	0,006	11,7	0,000
4 h	61,0	0,011	10,1	0,012	11,9	0,007
Batch III:						
0 h	63,1	0,012	11,7	0,001	9,9	0,001
1 h	63,0	0,007	9,6	0,000	11,7	0,000
2 h	62,5	0,009	9,1	0,006	12,1	0,001
3 h	61,9	0,011	8,5	0,006	12,4	00,01
4 h	61,4	0,007	8,4	0,010	12,6	0,007

Despite differences in the food additive compositions, the initial colors of fresh-cut surfaces of all the batches were similar. When the cut surfaces were exposed to air and light, color changes in terms of L, a, and b took place. The changes can be interpreted to mean in terms of visual impression as follows:

— L gradually decreased and to the same extend in each type of sausage. This means: the lightness of the colors slightly decreased and the cange was not dependable on the food additive composition.

— a decreased more during the first hours than later and the extents of the changes varied. This means: decrease in figures of a plus (ref. Figure 3) indicated a decrease of redness which was dependable on the food additive composition.

— b increased relatively more during the first hour of expose than later, the extents of changes slightly varied. This means: increase in figures of b plus (ref. Figure 3) indicated a increase of yellowness which was dependable on the food additive composition.

The three dimensions of colors determined indicated that the Hunterlab Color instrument was sensitive to detect color changes of sausages, which are of practical concern.

a/b Ratio. For illustrating the change of color, one might calculate the a/b ratio and follow its change as the function of time. In Figure 5 the a/b ratios of this experiment are plotted against time. The graphs clearly shows that the sausage Batch I retained the color somewhat better than Batch II and was drasticly more effective than Batch III.

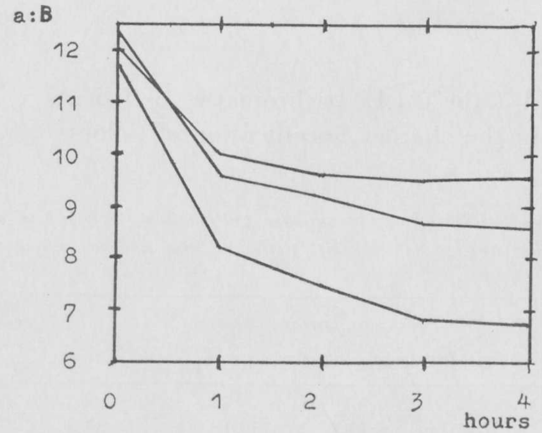

Figure 5. *The a/b Ratio of Colors of Sausage Cut Surfaces Exposed to Air and Light as a Function of Time.*

Total Color Difference (E). The total color difference change of a specimen within a period of time can computed from the Hunter-Scofield equation:

$\Delta E = ((\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2)^{1/2}$

In this experiment the total color change Δ E was also determined and in Figure 6 the Δ E figures are plotted against time. The graphs indicate the same result as the graphs a/b ratio over time.

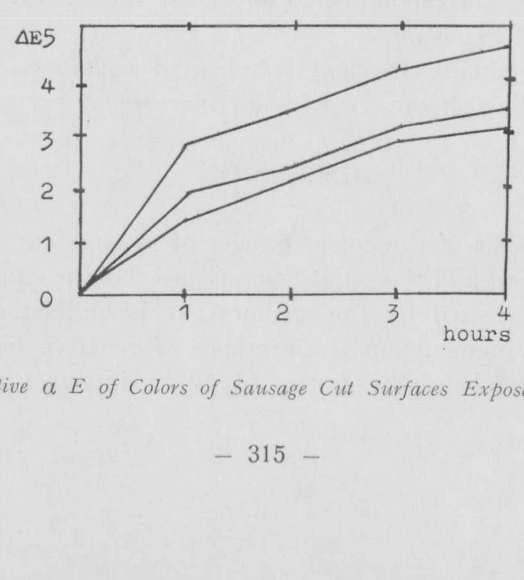

Figure 6. *The Additive* a *E of Colors of Sausage Cut Surfaces Exposed to Air and Light.*

C.I.E. Color Specification. The color dimensions, L, a, and b, can be converted into C.I.E. terms X, Y and Z:

$$Y = 0.01L^2$$

$$X = 0{,}9804 \left(Y + \frac{aL}{175}\right)$$

$$Z = 1{,}1810 \left(Y - \frac{bL}{70}\right)$$

From X, Y and Z the C.I.E. trichromatic coefficients x, y, and z can be derived as shown in the chapter Specification of Colors.

Table 2. *The colors, in C.I.E. terms, of sausage cut surfaces exposed to air and light. I, II and III are the sausage batches with different food addive compositions.*

	Fresh-cut surface			*After 4-hour exposure*		
	I	*II*	*III*	*I*	*II*	*III*
Y	40,2	39,7	39,18	37,3	37,2	37,7
x	0,361	0,362	0,361	0,368	0,366	0,365
y	0,334	0,333	0,334	0,341	0,342	0,347
z	0,305	0,305	0,305	0,291	0,292	0,288
D.W.1)	603	603	603	589	589	583
E.P.2)	14,3 %	14,6 %	14,5 %	22,2 %	22,2 %	20,0 %

1) Dominant wavelength, mμ, from C.I.E. chromaticity diagram.
2) Excitation purity, %, from C.I.E. chromaticity diagram.

The C.I.E. color specification did not produce as a distinct demonstration of color changes as the Hunterlab specification, the trends are, however, the same. The Y values, corresponding to lightness, indicated a decrease of lightness in 4 hours of exposure.

The shift of dominant wavelength indicated a change of color from reddish orange to yellowish orange with an increase of excitation purity.

DISCUSSION

The chemical basis of the color changes of sausage cut surfaces as modified by different food additives and demonstrated by instrumental color measurements is not studied by the authors. It is understood that chemical reactions of meat pigments in the presence of reactive food additives and oxygen as well as the catalytic effects of light are interactively involved. The reader is referred to the papers of Ramsbottom *et al.* (3) and Bailey *et al.* (4), which might be of interest in this connection.

CONCLUSIONS

Instrumental color measurements of sausage performed in this study with Hunterlab Color and Color-Difference Meter were found a rapid and accurate tool for product evaluation. It is believed that the application of an instrument to color evaluations in product research and development as well as in quality control of meat industry could serve as an useful technical aid. Research is needed, however, to establich the acceptable limits of color variations which should be used in production in order to meet the color preferences of the consumers.

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